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GENETICS

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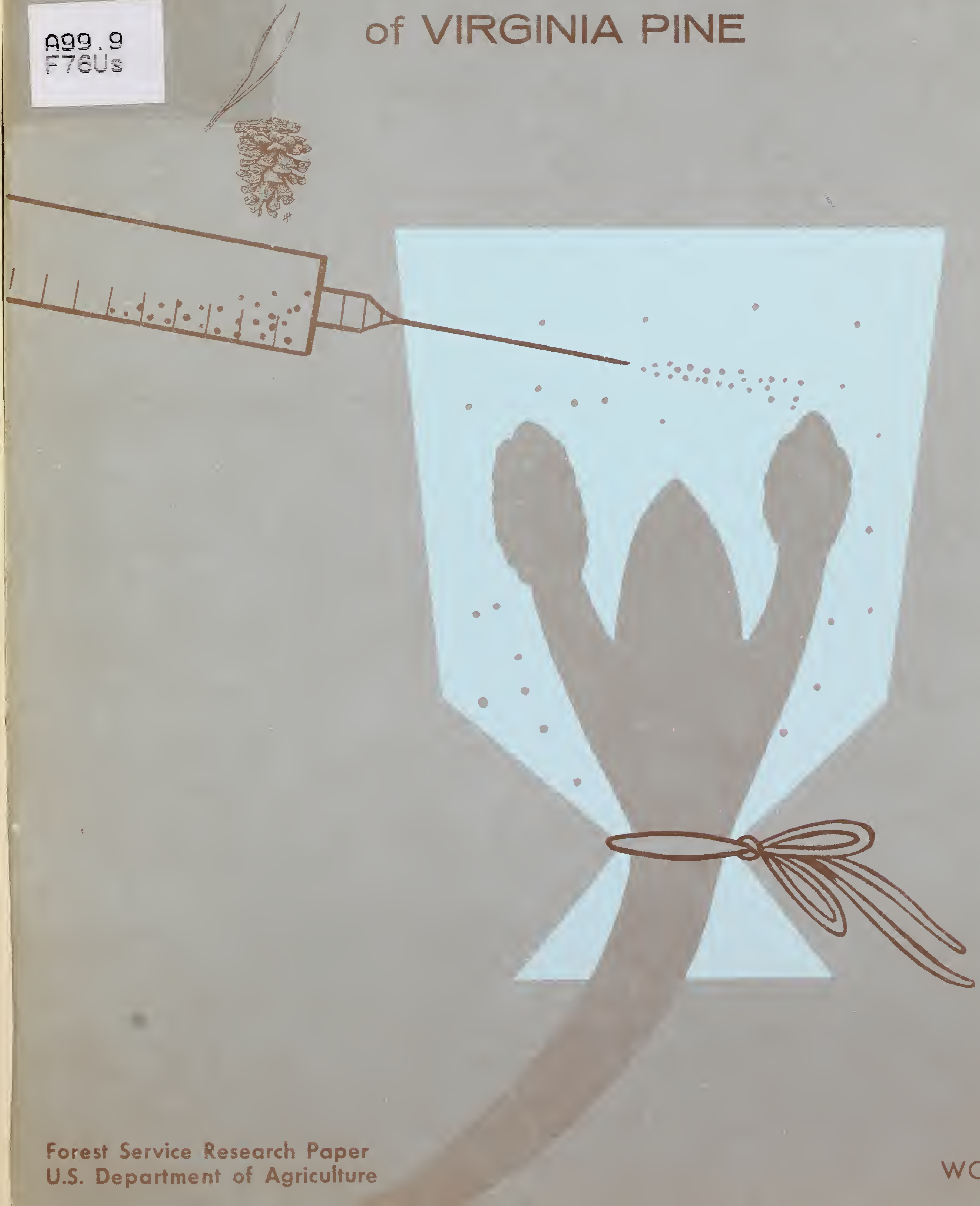
# of VIRGINIA PINE



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SUMMARY

Long considered to be a minor species of the southern yellow pines, Virginia pine is now being planted at the rate of several thousand acres annually. This activity has resulted in a wide-ranging tree improvement program which capitalizes on the large variation among trees. Clinal variation is weakly indicated for wood tracheid length but is absent for other characteristics studied. Two ecotypes are thought to exist although they have not been verified. The species hybridizes freely under controlled conditions with the Ocala race of sand pine but has not been successfully crossed with the other two species (lodgepole and jack pine) of subsection *Contortae*. Evidence is presented that Virginia pine and sand pine of subsection *Contortae* may have arisen from a cenospecies involving members of subsection *Australes*.

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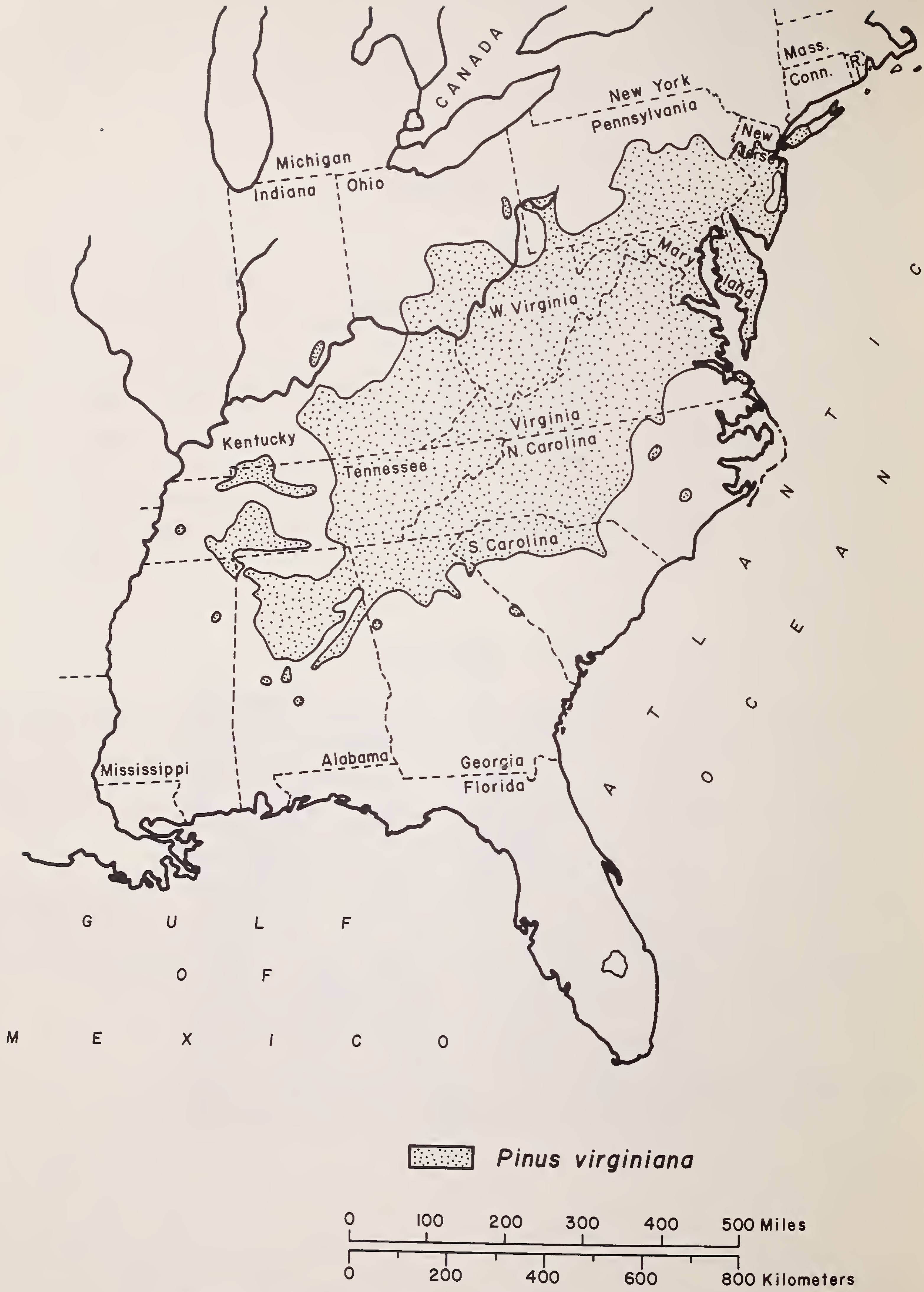

FIGURE 1.—The range of Virginia pine (Critchfield and Little 1966).

GENETICS OF VIRGINIA PINE

R. C. Kellison and B. J. Zobel[1]

INTRODUCTION

Pinus virginiana (Mill.), variously known as Virginia, Jersey, possum, spruce, shortstraw, scrub, poverty, and old field pine, is a species of contrasts. It is despised by the logger but liked by the forester and the pulp mill manager in most areas of its range.

The logger's negative reaction to Virginia pine results from the tree's small size and to its persistent branching habit, factors which adversely affect harvesting production. Dominant and codominant trees average only 23 to 25 meters tall and 28 to 30 centimeters at 50 years.[2] Older trees may attain heights to 35 meters and diameters to 90 centimeters (Harlow and Harrar 1950), but even they often retain branches and branch stubs the length of the bole below the live crown. Despite these deterrents, the species has gained the respect of foresters because of good volume and dry-weight yields at rotation ages of 25 to 30 years (Newland 1968, N.C. State Univ. 1970), and of pulp mill managers because of suitability of the fiber for fine paper and groundwood products. These attributes are responsible for a recent planting program of several thousand acres annually. Secondary uses of Virginia pine include lumber and structural timber from sawlog-sized trees, and Christmas trees which are harvested at rotation ages of 6 to 10 years.

This paper reviews the current status of research on the genetics of Virginia pine, with emphasis on its biology, and suggests directions for future tree improvement programs.

Natural Distribution and Habitat

Virginia pine is primarily restricted to the Piedmont and southern Appalachian provinces (fig. 1). Its range has been described by Livingston and Shreve (1921) as lying "between the northern and southern areas of the evergreen needle-leaved forests and almost wholly in the deciduous region." In this region the species is an aggressive pioneer of old fields where it usually forms pure stands (fig. 2), often on soils that have been severely eroded.

Formerly called *P. inops* (Ait.), Virginia pine is grouped with *P. clausa*, *P. banksiana*, and *P. contorta* to form subsection *Contortae*, section *Pinus*, subgenus *Pinus* (Critchfield and Little 1966). Young trees in forest stands have a sprucelike appearance because of their narrow, conically-shaped crowns and glossy foliage. Crowns of trees older than about 40 years are characterized by numerous open cones that persist from 5 to 15 years, by sparse foliage, and by an unbalanced appearance resulting from the loss of apical dominance. Trees growing in the open often develop a crown form similar to that of an apple tree, with persistent, heavy limbs to the ground. The fascicles, which have needles in clusters of two's and occasionally three's, remain alive for 2 or 3 years. The needles are short (4 to 6 cm.), stout, twisted, and bright green. The bark of young trees is smooth and grayish but breaks into brown, platy scales with shallow fissures at older ages.

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[1] Associate Director and Director, respectively, Cooperative Programs, School of Forest Resources, North Carolina State University, Raleigh, N.C.

[2] Kelly, Thomas H., Jr. Summary of available information on Virginia pine. Unpub. manuscript, School of Forest Resources, North Carolina State University, Raleigh, N.C.

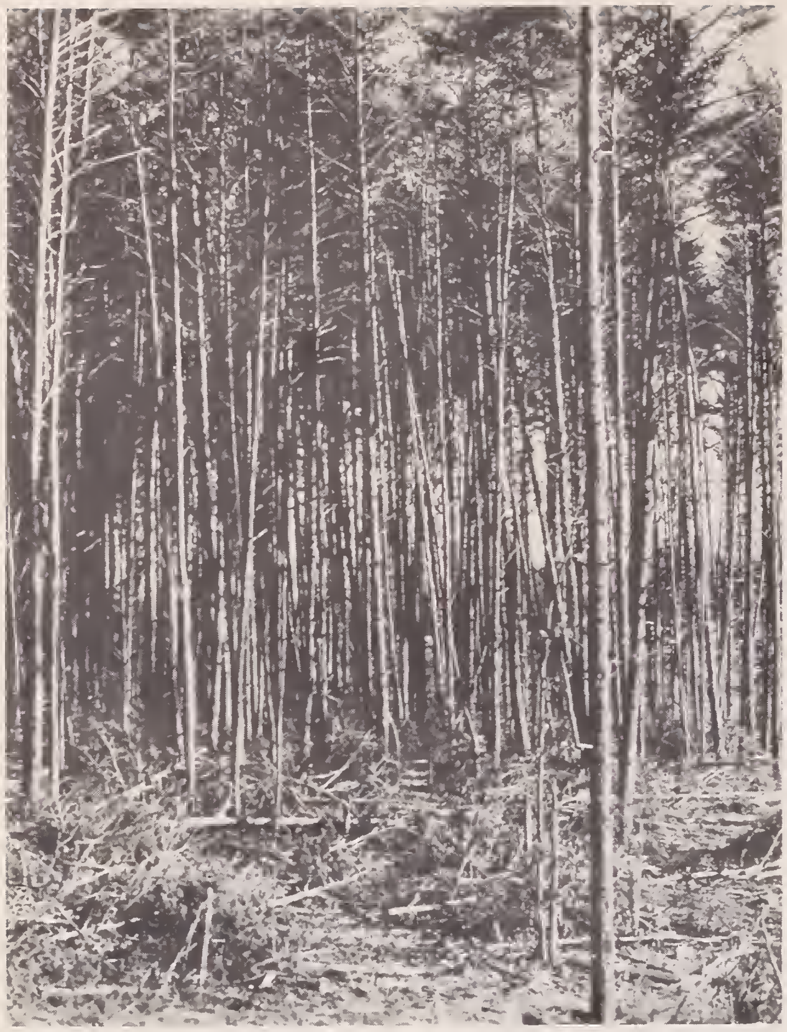

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FIGURE 2.—An old field stand of Virginia pine in the Piedmont of North Carolina. Note the density of the stand and the persistent branch stubs.

Virginia pine performs well on a variety of soils derived from crystalline rock, sandstone and shale, and to a lesser extent from soils of limestone origin (McIntyre 1933). Although commercial stands are generally restricted to areas of shallow topsoil because of less vegetative competition during the formative years, best growth is attained on deep topsoils of loam or clay loam. The species performs best at elevations below 500 meters but it occurs to elevations of 1100 meters[3] in the South and 600 meters in the North (Snow 1960). Except for areas in the mid-Atlantic States where it occurs on deep sands, the species has a shallow root system which makes it extremely vulnerable to windthrow along exposed edges; trees occurring on the deep sands have well-developed tap roots of 2 to 3 meters and have particular resistance to windthrow (Kundt 1972). The species is also vulnerable to breakage from ice and snow, particularly in the pole-sized state of development (Slocum and Miller 1953). Major insects attacking it are the Nantucket pine tip moth (*Rhyacionia frustrana*), pine bark beetles (*Dendroctonus* spp.), wood engravers (*Ips* spp.), and redheaded pine sawflies (*Neodiprion* spp.). No serious disease has been associated with Virginia pine, although it is attacked by gall rusts (*Cronartium comandrae* and *C. cerebrum*), pitch canker (*Fusarium lateritium*), root rot (*Fomes annosus*), and heart rot (*F. pini*) among others.

Taxonomy

The grouping of Virginia pine with *P. contorta*, *P. clausa*, and *P. banksiana* to form subsection *Contortae* (Critchfield and Little 1966) is the same as Duffield's Group XIII (1952) which he removed from *Pinus* group *Insignes* of Shaw (1914). The new classification recognizes the possibility that the four species are entities of a cenospecies extending from the Pacific to the Atlantic Oceans. *Pinus contorta* is native to western North America, extending from Baja California to the Canadian provinces of British Columbia, Alberta, Saskatchewan, and the Mackenzie District of the Yukon Territory. *Pinus banksiana* is common in the Lake States and the Northeastern States and extends from the Canadian provinces of Nova Scotia to Alberta and the Yukon Territory. These two species overlap and hybridize in Alberta and the Yukon, and introgression into lodgepole pine is likely (Mirov 1956, Critchfield 1957). Three hundred kilometers to the southeast of the range of *P. banksiana*, *P. virginiana* occurs in the general region of the southern Appalachians. There is a 160-kilometer separation between the ranges of *P. virginiana* and *P. clausa*, the fourth member of the group which is restricted to localized populations in central and northwestern Florida and southeastern Alabama.

Controlled crosses between *P. virginiana* and the two western species of subsection *Contortae* have been unsuccessful (Mirov 1967). The cross between *P. virginiana* and the Ocala source of *P. clausa* is made with ease in either direction under controlled conditions; seed from this cross, from *P. clausa* x *P. taeda*, *P. clausa* x *P. echinata*, *P. clausa* x *P. serotina*, and from *P. virginiana* x *P. taeda* are being tested for hybrid authenticity at the Institute of Forest Genetics, Placerville, Calif.[4] Such intergroup crossings involving subsection *Australes*, to which *P. taeda*, *P. echinata*, and *P. serotina* belong, and subsection *Contortae* are not unknown; hybrids of *P. elliottii* x *P. clausa* have been verified (Saylor and Koenig 1967). The karyotype of *P. virginiana* is only slightly less similar to that of *P. taeda* and *P. palustris*, the latter being still another member of subsection *Australes* (Saylor 1972), than it is to the karyotype of other members of subsection *Contortae*. The behavior of *P. virginiana* and *P. clausa* may indicate that they originated from a different progenitor than *P. banksiana* and *P. contorta*, or that they are members of a cenospecies involving members of subsection *Australes*.

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[3] Personal observation in western North Carolina and northern Georgia.

SEXUAL REPRODUCTION

Virginia pine is monoecious, although some trees are largely dioecious for staminate strobili production (fig. 3). Reproductive development is attained in five years or less when crown and root competition is minimal, but heavy strobile production may be delayed for forty years in the pure, dense stands so characteristic of the species. Once cone and seed production is initiated, some crop is produced every year and bountiful crops are obtained about every three years (Sterrett 1911, Potzger 1932, Slocum and Miller 1953).

Staminate strobili occur in clusters of 10 to 40 at the base of new growth, generally in the lower part of the crown. Pistillate strobili which are generally equally distributed throughout the crown, occur singly and in whorls of two to eight along the elongating shoot. The most distally positioned strobili, which are almost always borne singly, often flush from 7 to 10 days later than those near the base of the new growth. Morphogenesis of both types of strobili occurs in late June and July of the year preceding strobili development and pollination. Male strobili are often identifiable in late autumn and winter of the same year in which they are formed, but the females are difficult to distinguish from vegetative buds until shoot elongation is initiated the following spring.

The pistillate and staminate strobili mature approximately simultaneously, with anthesis occurring from late March to late May from the southern to northern extremities of the range, respectively (Snow 1960). Fertilization is consummated about

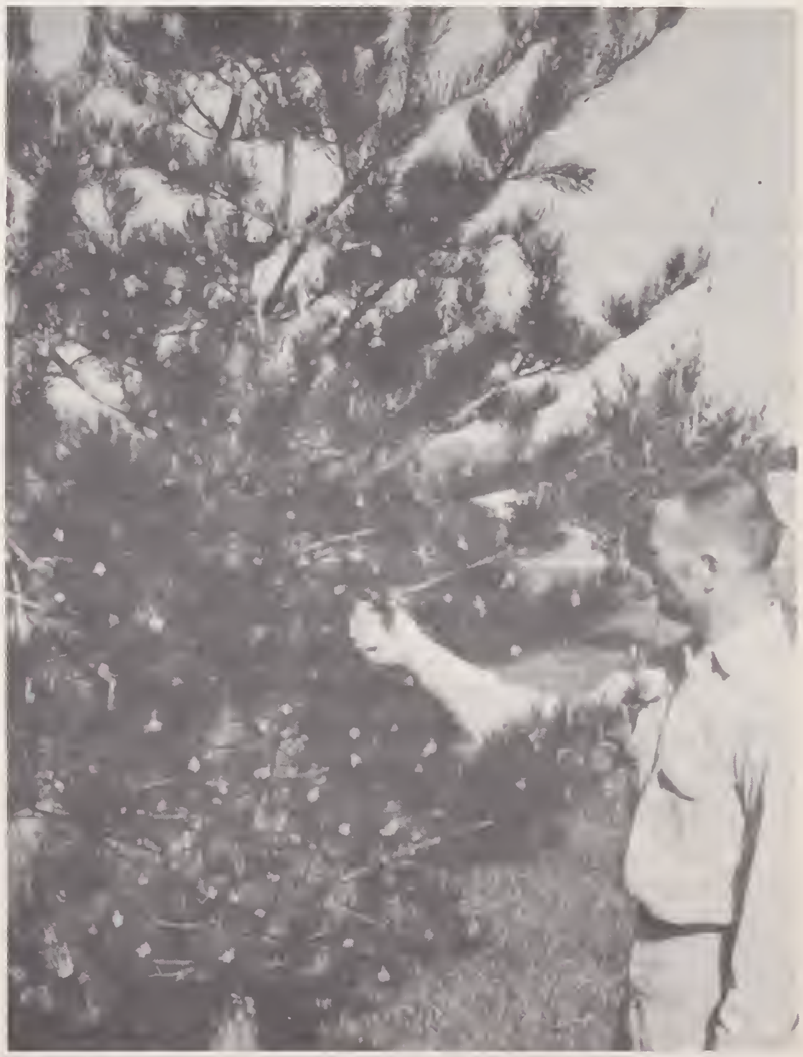

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FIGURE 3.—A graft in the Virginia pine seed orchard of Hiwassee Land Company at Vonore, Tenn., which produces staminate strobili to the almost total exclusion of pistillate strobili.

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[4] Personal communication with Ray Brown, Hoerner-Waldorf Corporation, Roanoke Rapids, N.C. Mr. Brown has effected these and other crosses intermittently for many years in his employer's pine arboretum at Tillery, N.C.

13 months after pollination (Thomas 1953), after the cones have enlarged to nearly full size (5 to 8 cm.). The ensuing seeds are fully viable by mid- to late August (Church and Sucoff 1962), but they are difficult to extract until the cones have been preripened or until they ripen on the tree about 2 months later. Preripening is best accomplished by exposing a single layer of green cones to the environmental elements, including full sunlight, until the scales begin to separate (N.C. State Univ. 1968). Seed dispersal from tree-ripened cones begins from mid- to late October. The majority of sound, viable seeds is shed within the next 2 months, but some seeds remain in the cones until February or March of the following year.[5]

Cross- and Self-Pollination

Virginia pine is an outcrossing species although selfing does occur. The opportunity for selfing is greater in this species than in other yellow pines of the region because of the occurrence of pistillate strobili in the lower section of the crown, in juxtaposition with staminate strobili. Natural selfing in loblolly pine has been estimated to occur at a frequency of 2 percent in the upper crown and at 31 percent in the lower crown (Franklin 1969); but for this species the pistillate and staminate strobili are generally restricted to separate zones of the crown, theoretically resulting in less selfing than would be encountered in Virginia pine.

Almost certainly, considerable inbreeding other than selfing is extant in Virginia pine because of the reproductive habits of the species. A few remnant trees along fencerows and watercourses are often the only source of seed for the natural regeneration of large acreages. Crossing among the resultant progenies, which likely have at least one parent in common, could quickly lead to inbreeding depression.

Controlled Pollination

Pistillate strobili should be isolated when the scales of the reproductive bud change from greenish-brown to whitish, but before the reddish scales of the conelet are visible. Earlier bagging often results in mistaken identity of vegetative buds for reproductive buds, and later bagging increases the probability that contamination by a foreign pollen has already occurred.

Results from the North Carolina State-Industry Cooperative Tree Improvement Program indicate that 70 percent of the control-pollinated conelets of Virginia pine abort before cone maturity, with most of the abortion occurring within 8 weeks after pollination. This loss, compared to the loss of about 25 percent of open-pollinated conelets, is probably caused by poor pollination techniques. Contact between the conelet and the isolation bag is another cause for loss or damage of the conelets. Remedial measures to prevent this occurrence include the use of wire frames which extend from the bag to a rigid part of the branch. Pollination bags supported by wire frames are shown in figure 4.

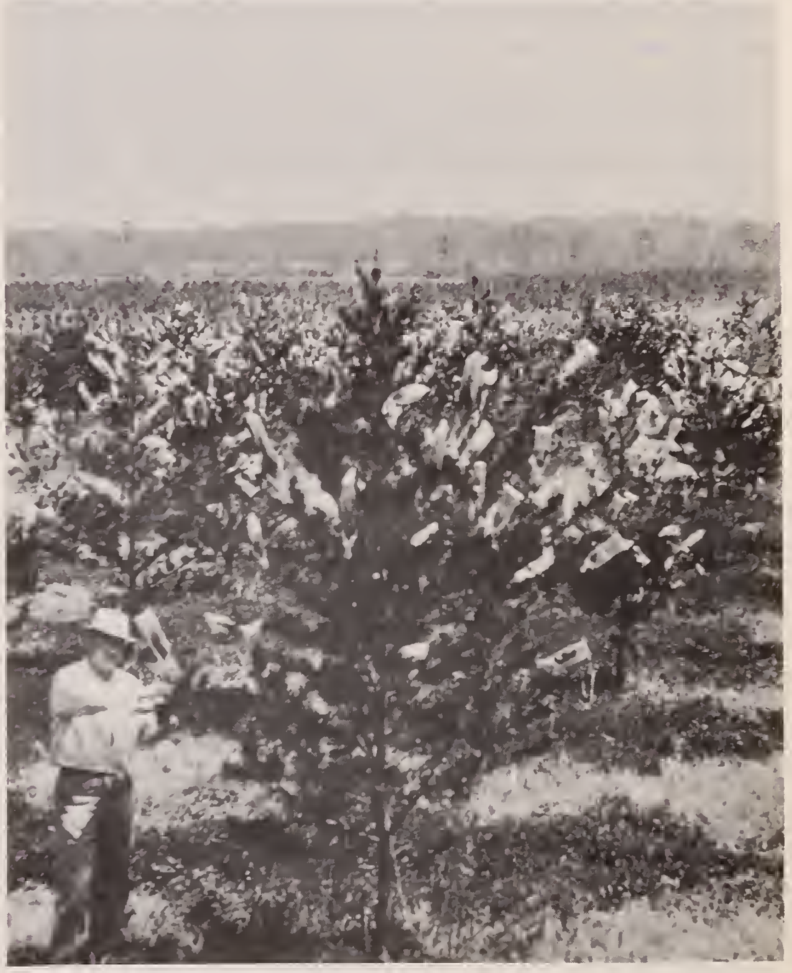

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FIGURE 4.—Isolated pistillate strobili of Virginia pine in readiness for controlled pollinations for progeny testing. The location is the seed orchard of Kimberly-Clark Corporation, Coosa Pines, Ala.

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[5] Report submitted to the Seed Harvest Committee of the North Carolina State-Industry Cooperative Tree Improvement Program by Walter Chapman, Regeneration Forester, Kimberly-Clark Corporation, Coosa Pines, Ala.

Seed Germination and Establishment

The seeds of Virginia pine are small, averaging 88,000 to 172,000 per kilogram from natural stands (Snow 1960), and 84,000 with a clonal range of 60,000 to 97,000 from 22 clones in a central Alabama seed orchard. In the seed orchard study, no apparent relationship was found between seed size and germination percent, nor between seed size and total height of 10-month-old seedlings (Kundt 1972).

Germination of apparently filled seeds averages 55 percent, with a range from 30 to 90 percent (Slocum and Miller 1953, Snow 1960, N.C. State Univ. 1970); no differences are found in germination of seeds from different parts of the cone (Stone 1933). Records of two Tennessee Valley Authority nurseries for an 18-year period show about 16,500 plantable seedlings being produced per kilogram of seed. The production ratio increased, however, in direct relation to improvements in nursery practices (Gouffon 1947).

Germination of Virginia pine seeds is not enhanced by stratification (Kundt 1972). The seed will germinate on most soils provided the soils are loose enough to receive the radicle. The resulting seedlings will develop in harsh environments such as in severely eroded fields where only the parent material remains, but they are intolerant to shade (Miller 1951). Nursery production of Virginia pine seedlings differs little from production of other yellow pines of the region. The seedlings are generally outplanted as 1–0 stock at spacings of about 2.5 × 2.5 meters.

ASEXUAL REPRODUCTION

In nature, no instance has been reported of asexual reproduction of mature Virginia pine by sprouting, layering, or rooting of separated twigs.

Rooting

Rooting of Virginia pine is not an accepted practice for preserving or multiplying desired genotypes because of the poor success achieved. In our repeated attempts to root cuttings from 1-year-old seedlings, from 3-year-old grafts of mature trees, and from 40- to 50-year-old select trees of the same genotypes as the grafts, we obtained 52 percent success from the seedlings but failed completely to root the other two types of cuttings.

Grafting

Grafting is the operational method used to asexually reproduce Virginia pine (fig. 5). Many thousands of grafts are made annually for establishment of clonal seed orchards and clone banks. The type of graft made is dependent upon the preference of the operator, but the one having widest acceptance is the dry-side graft (Webb 1961). Dormant scions are grafted onto dormant rootstock or onto rootstock just beginning vegetative growth. Scions can be collected and stored for 6 weeks prior to grafting with little loss in graft survival; however, best success is achieved by grafting freshly collected scions.

Grafting success of Virginia pine is generally about 65 percent as compared to 85 percent for the major yellow pines of the region. One reason for the difference is the thin, flexible scions of Virginia pine which are extremely difficult to cut to assure the good stock-scion interface so essential to successful grafting. A second reason is the greater susceptibility of Virginia pine grafts to mold than is encountered with grafts of the other southern pines.

Best grafting success is achieved when vigorous rootstock is used. Grafting in greenhouses, in grafting beds, or in-place within the ensuing seed orchard has been about equally successful. However, unexplained delayed mortality often encountered with transplanted grafts of Virginia pine has caused many seed orchard operators to favor in-place grafting.

GENETICS

Genetic, silvicultural, and management studies of Virginia pine have revealed large tree-to-tree and stand-to-stand differences, but the classical ecotypic or clinal variation is only weakly indicated (Thor 1964, Evans 1971). The populations of the Talladega Mountains in central Alabama and those occurring on the deep sands of the mid-Atlantic states are suspected of being distinct ecotypes, but there is very little evidence to support the supposition. Trees of the Talladega Mountains are characterized by vigorous growth, by whitish to grayish bark, and by cones that are singly borne and largely deciduous (personal observation). Evaluating 17 sources representative of the species range, Genys (1966) found that the source from Alabama as well as sources from Tennessee, South Carolina and Virginia, survived and grew poorly when planted on a harsh site in northeastern Pennsylvania. The sources performing best were the high elevation ones proximal to the planting location. When planted in Maryland and Tennessee, the Alabama source was average to below average in growth and survival to the local sources. There was no planting in Alabama to evaluate the goodness of the local source, but, assuming that an ecotype does exist for the Alabama population, these results indicate that it should not be planted very far north of its immediate range.

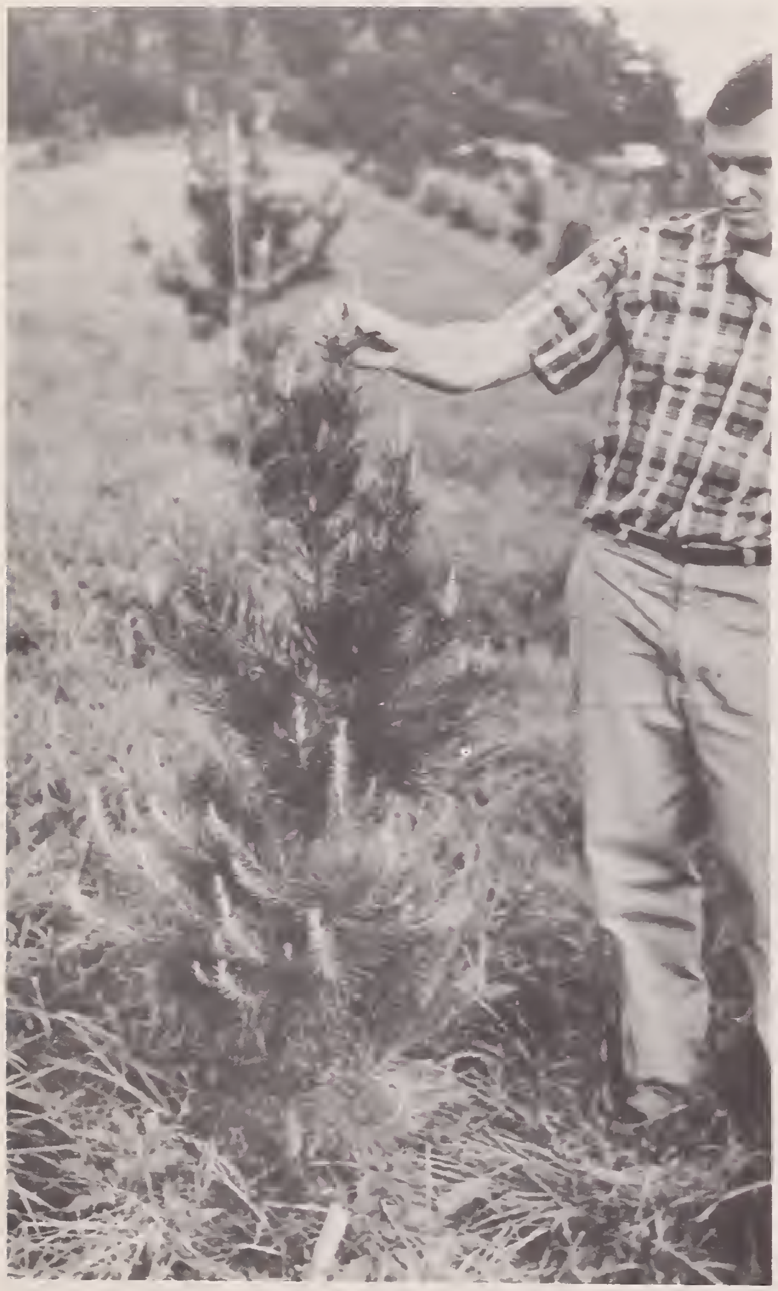

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FIGURE 5.—A 2-year-old graft of Virginia Pine in the seed orchard of Catawba Timber Company, Catawba, S.C. Note the difference in texture of foliage between the stock and the scion.

Clinal variation has been shown for tracheid length of Virginia pine in the Cumberland Plateau and mountains of Tennessee and Kentucky (Thor 1964). Longer tracheids at breast height from both the 10th and 25th annual rings are found at the more northerly latitudes. In the same study in which 15 trees each from 13 native stands were investigated for wood properties, stands from the Great Valley of Tennessee had higher unextracted wood specific gravity (.528 to .506) and greater amounts of extractives (.034 to .020 g/cm) than those to the north and west. No such trend existed for extracted wood specific gravity.

The greatest source of variation observed in wood properties of Virginia pine has been among trees within a stand, with less variability existing among samples within trees and among stands (Thor 1964) (table 1). Similar conclusions were obtained by Saucier and Taras (1969) from a study of 244 trees from natural stands in north Georgia and east Tennessee. Mean unextracted specific gravity of increment cores was .50, with individual tree values ranging from .40 to .60. No evidence of a geographical trend existed. In a related study of 2,114 trees growing throughout the species range, mean specific gravity of unextracted increment cores was .449, with a standard error of the mean of .009 and a standard deviation around individual observations of .055 (Clark and Wahlgren 1970). They found little difference in specific gravity between extracted and unextracted increment cores and no evidence of geographical trends in specific gravity in either the north-south or east-west directions.

TABLE 1.—*Relative percentage of the total variation of wood properties of Virginia pine accounted for by stands, trees within stands, and samples within trees in Tennessee and Kentucky*[1]

Characteristic	Relative percentage of total variation		
	Stands	Trees within stands	Samples within trees
Radial growth	21	47	32
Sp. gr. (unextracted)	14	57	29
Extractives	29	38	33
Sp. gr. (extracted)	4	68	28
Tracheid length (10 yrs.)	32	56	12
Tracheid length (25 yrs.)	46	45	9

[1] From Thor 1964.

TABLE 2.—*Unextracted specific gravity of select and comparison trees and tracheid length of summerwood cells from the 15th and 30th annual rings at breast height of select Virginia pine trees in the North Carolina State Cooperative Tree Improvement Program*

Source (province & State)	Number of trees	Unextracted sp. gr. of mature wood	Number of trees	Tracheid length 15th ring	Tracheid length 30th ring
Piedmont:				*Mm.*	*Mm.*
Virginia	426	.51	71	3.49	4.00
North Carolina	372	.52	47	3.55	4.43
South Carolina	96	.54	16	3.55	4.23
Alabama	252	.50	42	3.48	4.03
Tennessee	60	.50	10	3.69	4.33
Total or average	[1] 1206	[2] .51	[1] 186	[2] 3.52	[2] 4.15
Mountain:					
West Virginia	18	.50	3	3.55	3.94
North Carolina	60	.52	10	3.45	3.93
Tennessee	120	.51	20	3.45	4.03
Georgia	12	.54	2	3.64	4.40
Total or average	[1] 210	[2] .51	[1] 35	[2] 3.47	[2] 4.01

[1] Total.
[2] Average.

No clinal or ecotypic pattern of variation was found for unextracted specific gravity of mature wood[6] or for tracheid lengths of summerwood cells from the 15th and 30th annual rings of breast height samples from trees selected for seed orchard use in the North Carolina State Cooperative Tree Improvement Program (table 2).

Variation among trees in growth, form, prunability, and site adaptability is equally as great as the variation in wood properties. A geographic variation study of Virginia pine in Tennessee and Kentucky yielded the following results (Evans 1971): (1) Sources from the Great Valley of Tennessee and Kentucky were taller after two growing seasons at all six planting locations than those from the north and west; (2) narrow-sense heritabilities for a characteristic varied considerably among planting locations but averaged 0.28 and 0.28 for first- and second-year height growth, 0.21 and 0.16 for second-year branch length and branch diameter, and 0.20 for second-year stem diameter; and (3) genetic gains for second-year height growth of 21 percent were predicted from selection of the tallest individuals in the tallest 45 families, and 25 percent from selection of the tallest individuals of the tallest 45 familes of the tallest seven stands.

From a half-diallel crossing of 22 clones of Virginia pine, Kundt (1972) obtained narrow-sense heritabilities from 10-month-old seedlings as follows: Total height, 0.09 to 0.14; stem diameter, 0.03; number of branch whorls, 0.21; and terminal bud set, 0.13. These heritabilities are relatively low, but they are expected to increase with age of the plant material.

The type of variation shown from these two progeny studies indicates that the species is well suited for genetic improvement through a selection program. However, this conclusion cannot be made with finality until results are available from progeny tests of an age about one-half of rotation age.

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[6] Wood formed beyond about the 10th annual ring.

IMPROVEMENT PROGRAMS

Tree improvement of Virginia pine is less advanced than it is for the major yellow pines of the region but rapid progress is being made. Within the past 8 years more than 300 trees have been selected (fig. 6) and 80 hectares of seed orchards have been established. Some of the orchards are in full production, yielding seed for production of 1,250,000 plantable seedlings per hectare of seed orchard annually. Seed for approximately 5 million seedlings were collected from seed orchards in 1971.

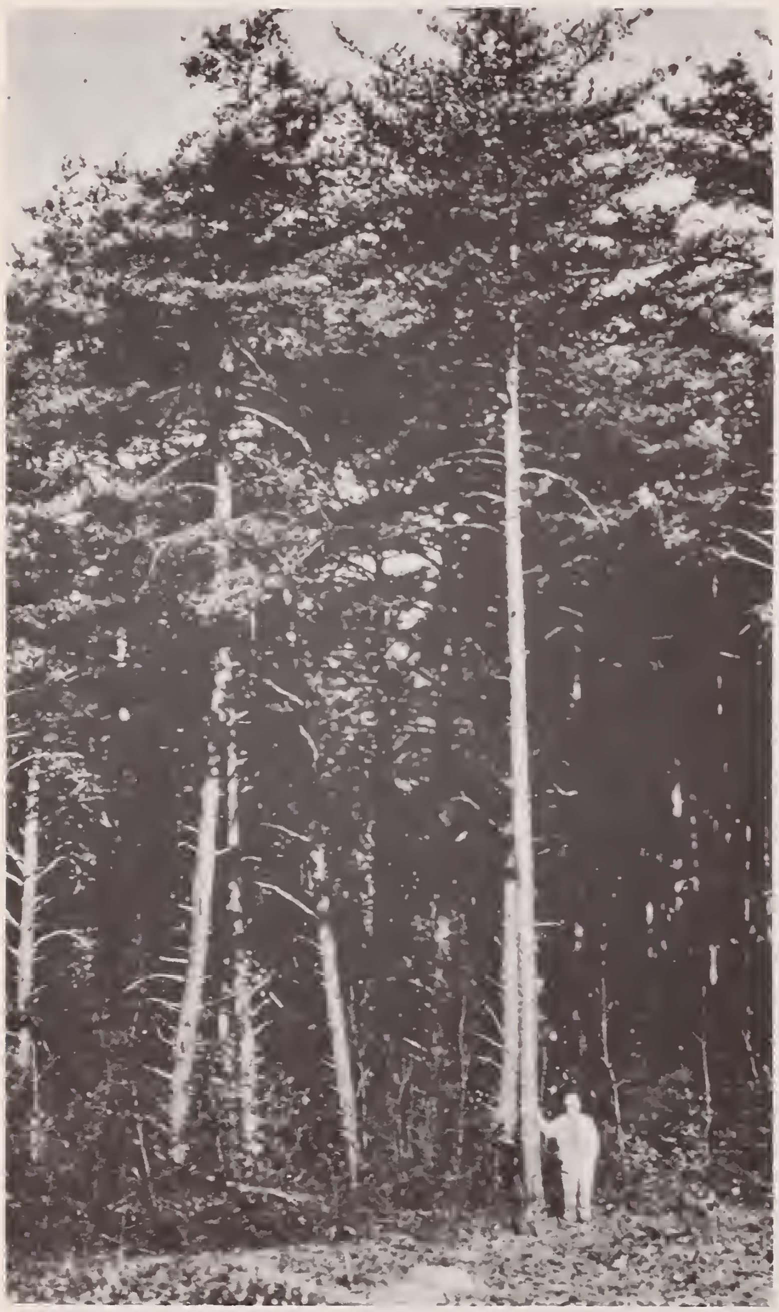

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FIGURE 6.—A Virginia pine tree selected for use in the seed orchards of the North Carolina State University Cooperative Tree Improvement Program. Note the superiority of the selected tree in pruning and in form.

Early results from progeny tests of select trees indicate that genetic gains in Virginia pine will be equal to or greater than those obtainable in other pines of the region. A comparison of 13 open-pollinated families with the commercial check showed the selects to have a height advantage of 19 percent at 3 years of age and 11 percent at 5 years of age (table 3).

TABLE 3.—*Progeny performance of 13 select trees and a commercial check (c.c.) at 3 and 5 years of age*[1]

Category	3-year performance		5-year performance	
	Height	Superiority to c.c.	Height	Superiority to c.c.
	Meters	*Percent*	*Meters*	*Percent*
Best 4 families	1.30	25	2.58	18
Poorest 4 families	1.15	11	2.30	5
All 13 families	1.24	19	2.54	11
Commercial check	1.04	0	2.19	0

[1] Results are from the progeny test of Westvaco Corporation, Charlottesville, Va.

The best four families were taller by 25 percent at 3 years and by 18 percent at 5 years, and even the four poorest families were superior in height to the commercial check. It is significant that there is a distinct height advantage in progenies of select trees compared to the commercial check in all open- and control-pollinated progeny tests of Virginia pine established to date by the North Carolina State Cooperative Tree Improvement Program (table 4 and fig. 7).

Because both pistillate and staminate strobili production are initiated at 5 years of age or less in trees free of competition, Virginia pine is well suited for use in seedling seed orchards and for experimental breeding purposes. Both alternatives have received limited attention, although at least two seedling seed orchards have been established within the range of the species.

Breeding experiments of Virginia pine have been limited because of the delayed interest in the species for commercial use, but considerable research is now being

TABLE 4.—*Performance of open- and control-pollinated progeny of select trees and their commercial checks (c.c.) within the North Carolina State Cooperative Tree Improvement Program.*

Cooperator and location	Age when evaluated	Number of families (excluding c.c.)	Average height of families by type of cross		
			Control	Open	C.c.
			Meters	*Meters*	*Meters*
Westvaco Corporation Charlottesville, Va....	3	13	....	1.24	1.04
Westvaco Corporation Charlottesville, Va....	5	13	....	2.54	2.19
Hiwassee Land Company Calhoun, Tenn.	4	12	....	2.14	2.00
	4	11	....	2.39	2.03
	4	8	2.80	....	2.54
	4	3	2.56	....	2.15

initiated as shown: (1) An attempt is being made to create synthetic varieties by crossing among the best selected trees from throughout the species range;[7] (2) some progress has been made in selfing Virginia pine to create inbred lines for future breeding programs;[8] and (3) heritability estimates of commercially important characters are being determined.[9]

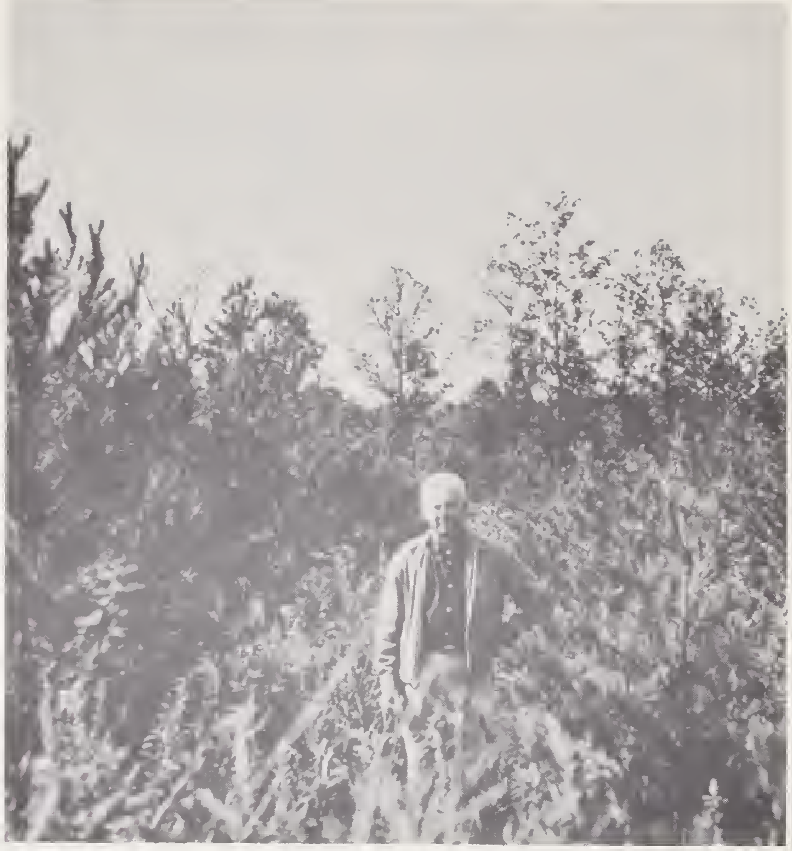

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FIGURE 7.—**Control-pollinated crosses of selected Virginia pine perform consistently better than do the commercially available seedlings. Seedlings in the row on the man's immediate left are commercial stock, and those on his right are control-pollinated stock from selected trees. The planting is on lands of Hiwassee Land Company, Calhoun, Tenn.**

Only when results from such studies are obtained will a workable knowledge of the genetics of Virginia pine come to fruition. Enough is already known to be certain that useful responses will be obtained from genetic manipulation of this species.

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[7] Personal communication with Dr. J. F. Goggans, Auburn Univ., Auburn, Ala.

[8] Personal communication with Dr. Roland Schoenike, Clemson Univ., Clemson, S.C.

[9] Personal communication with Dr. Peter Feret, Virginia Polytechnic Institute and State University, Blacksburg, Va.

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KELLISON, R. C., and B. J. ZOBEL
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Long considered to be a minor species of the southern yellow pines, Virginia pine is now being planted at the rate of several thousand acres annually. This activity has resulted in a wide-ranging tree improvement program which capitalizes on the large variation among trees. The current knowledge of Virginia pine genetics is summarized under the headings: (1) Introduction – Natural Distribution and Habitat, Taxonomy; (2) Sexual Reproduction; (3) Asexual Reproduction; (4) Genetics; (5) Improvement Programs; and (6) Literature Cited.

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